Episode 11: Of Matters Dark...
Physicists: Ken Clark, Amanda Bauer

Transcribed by Denny Henke

Ben: Over the course of my studies in theoretical physics I've traveled across the continent and around the world sampling new ideas and tasting different answers to the questions of how and why. And still I find there remains a deep hunger which lives within me, a burning desire to share these great ideas with the people around me. And so, I have assembled a team of some of the greatest, most lucid, most creative minds, I have encountered in my travels and I call them my Titanium Physicists. You're listening to the Titanium Physicists Podcast and I'm Ben Tippett. And now allez physique!

[1:48]

Ben: Dark matter. We owe the name to Fritz Zwicky, the ground breaking astronomer who called his co-workers spherical bastards because apparently they were bastards regardless of which angle he looked at them from. There's a constellation called Coma Berenices which is Greek for Berenice's hair and it's near the constellation of Leo. And in this constellation there is a cluster of galaxies called the Coma Cluster and Fritz Zwicky was looking at how fast the galaxies were orbiting each other. See, in astronomy, if you know that a celestial object is gravitationally trapped in a system there is a relationship between how fast it will move and the mass of the system. So, Zwicky was trying to figure out how much mass there was in this cluster of galaxies. And, there's an alternative way to figure out how much mass a system should have. From hermetic philosophy, we have the phrase, as above, so below and it turns out that this isn't such a bad axiom for studying astrophysics. For instance, the same universal law of gravity which binds the moon in orbit around the earth can also be used to describe huge galaxies in orbit around one another. One thing which is true in our solar system is that most of the mass is concentrated in the sun. All of the mass of everything in the solar system put together is only about 1/1000th of the mass of the sun. If this was generally true then we should be able to determine how much mass there is in a galaxy by counting up the number of stars in it. So, there were two ways for Zwicky to figure out how much mass the Coma Cluster had. He could look at the velocity of each galaxy or he could figure out how many stars there were in each galaxy and figure out how much luminous matter the galaxies had in total. Zwicky found a problem though. By looking at the velocities he got a number for the mass which was 200 times higher than the number he got by counting up all of the luminous matter. But that's okay, he argued that the difference in the two accountings of the mass came from the presence of what he called dark matter. So, that was 80 years ago and to be fair, Zwicky's observation occurred only 11 years after astronomers began to agree that there were other galaxies beyond the Milky Way. So, it's not so strange that Zwicky saw things that couldn't be explained. But the problem is that his dark matter has persisted. In almost every modern astronomical observation of galactic scale and beyond we've seen evidence of it. So, here's what we know. We know that it's not emitting or absorbing light. We know that every galaxy is filled with a ball shaped distribution of the stuff. And we know that for every star in the universe there's something like 50 stars worth of mass composed of dark matter. In our own Milky Way there's something like 20 times more dark matter than regular matter. So, dark matter. How do we know it exists and what the hell is it. Today, I'm pleased to announce that my guest is Kai Nagata. In 2010 Kai was CTV's Quebec City's bureau chief until he quit his job in 2011 because Canada's going down the crapper and the media is letting it happen. His open letter essay titled "Why I Quit My Job" made waves around the country and I hope it's message isn't forgotten. He works for the Tyee now, a multi Murrow award winning online news magazine. Hey Kai, how's it going.

Kai: Man, it's going great. I'm so confused already. I hope that the next little while I can unravel some of the mysteries that you have so delicately wound together like a ball of terrifying yarn.

Ben: Well, the yarn is terrifying but I've got two fantastic experts today to help you unravel it. So, Kai, today I've assembled two of my best Titanium Physicists. Arise Dr. Ken Clark!

Ken: Whoosh!!

Ben: Wow, he came in on a breeze. So, Dr. Ken did his undergraduate at the University of Toronto and his Masters and PhD at Queens University. He's now at Penn State working on Ice CUBE. And now arise Dr. Amanda Bauer.

Amanda: zzzzzwwwwwwwrrrrrrsssssshhhhooop.

Ben: Nice!! Dr. Amanda did her PhD in Austin Texas and she is a super science fellow at the Australian Astronomical Observatory in Sidney where she studies galaxy formation. She also blogs under the name Astro Pixie and we'll post your blog link on our website.

So, let's start talking about dark matter.

[6:01]

Amanda: Okay. Well, in addition to noticing that galaxies move around their clusters a bit quicker than what we can account for by all the luminous matter, in the 1970s Vera Rubin also noticed that within individual galaxies there was a similar velocity problem in that the stars in the very outskirts of the galaxies were moving entirely too fast for what we would assume they should be from just the gravity from the other stars within the galaxy. It's much different to what we see in our solar system. As you mentioned, in the solar system the mass is dominated by the sun and then you can calculate the velocities at which the planets move around based on how far away they are. So, Mercury, Venus and Earth feel the gravity quite strongly and move very quickly whereas Neptune and Pluto don't feel the strength of the sun's gravity as strongly because they are so far away. So, they move, very, very slowly around in their orbit around the sun. So, you would expect that in galaxies, since you look at them, you see a dense amount of stuff right at the center, you'd think that the stars near the center would be moving very fast and the stars at the outskirts would be moving very slowly but that's absolutely not what we measure at all. We see that the stars in the outside move as quickly as the ones in the center so this rotation curve describes how the velocity of the stars as you move out towards the outskirts of the galaxy and we call it flat because the stars on the outside are moving just as quickly as the ones on the inside. So, it has to be something else creating gravity that's causing these stars to move so quickly that is not also producing light.

Kai? So, it's kind of like you're playing tether ball but the ball is just whipping around way too fast.

Amanda: Exactly. So, what is that tether, that's the problem.

Kai: This mysterious force of gravitational pull, is that occupying the same space as the sun or do they overlap?

Amanda: Well, we don't see that there's very much dark matter inside of our solar system so it's not affecting each individual planet's gravitational field with the sun but we do see it in the solar neighborhood. So, it does look like stars that live nearby our sun are also moving a bit quicker than they should be based on the rest of the stars around. So, it's all the way throughout our galaxy and it extends even a bit beyond the edges of where the stars are in our galaxy. At least that we can see.

Kai: If things are orbiting around the central point then I can understand that they would move at speeds relative to their own mass and I guess the mass of the thing that's attracting them. I guess what's crazy is that something in the solar neighborhood, as Amanda puts it, could affect the rotational speeds of things inside of, you know, closed loops like the orbit of our planets around our sun. That's what's blowing my mind.

Ben: So, what's going on here is that here, orbiting around a loop, the speed at which you move around that loop will depend on how much mass is contained inside of that loop. So, the more mass there is, the faster you can go.

Amanda: Well, the more mass there is and how close you are together.

Ben: Yeah, that's right. What happens in the solar system is all of the mass is concentrated in the center so the farther you you get there's no more additional mass in between you and the sun but you're getting farther away so the farther you are from the sun in our solar system, the slower your orbit will be. And so, when astronomers did this type of calculation for the galaxy what happens is as your orbit loop gets wider in the galaxy it encompasses more matter, okay. There's more stars so they say, okay, if your orbit is very close to the center you can count up the number of stars in that loop and figure out how much mass there is and you get a fairly good description of fast you should be moving around the thing. And then as you expand your loop wider and wider you can still count up the number of stars inside that loop and try to figure out how fast you should be able to move around the loop. But when you do that on the galactic scale you count up all the stars and the stars that are moving around this loop end up moving much faster than they should be able to based on the number of stars inside that loop.

Kai: Gotchya.

Ben: So, there's an invisible mass problem. Somehow, there's a lot more mass inside that loop than there should be.

Kai: You're talking about the velocity, rotational curves, I'm wondering, is that the only way we can surmise the existence of this extra mass.

Amanda: Well, there are other observational pieces of evidence and one is called gravitational lensing and this is predicted from Einstein's general relativity. When light travels across space and comes close to some gravitational things, a galaxy or cluster of galaxies, as a result the light path actually bends. So if you have a galaxy that's directly behind some galaxy cluster, as that far distant galaxy's light travels around that cluster towards us, it actually get's bent around the cluster.

Kai: How much of a bend are we talking about? This has nothing to do with refraction, right? Like if you put a stick into the water and it looks bent. That's a totally different phenomenon from what you're talking about, right?

Amanda: Actually, it's quite similar. If you look through, say, a window on a clear day, you might not even be able to tell that glass is there. But if you have a raindrop on the window, if you look through that raindrop you can see that object outside completely distorted in almost like a ring manner and that's essentially what the cluster is doing to the galaxy behind it. It's distorting that light in the same way.

[10:57]

Kai: Okay, yeah, that makes sense.

Ben: We were talking earlier about windows, have you ever looked at really bad glass windows where there are visible warps in it?

Kai: Yeah, totally.

Ben: So, as light moves through space these warps, they're caused by gravity, so, the more massive it is the higher its warping. And it gets to the point that if one of these really heavy objects passes between a far off galaxy and us it will bend the shape of the galaxy out so much that it will make the shape of this galaxy look like a donut. This gravitational lensing actually visible looks like something passing through a really, really badly warped piece of glass.

Kai: Which could be a good thing like if, you know, you're talking about a bathroom window. You might want that effect.

Laughter.

Kai: Maybe the extraterrestrials just don't want us to, you know, look at their bits. It could be totally deliberate, it's just a way of throwing off our telescopes so we don't pry.

Amanda: So, that's exactly the point and then using these generally relativity equations we can say we see this galaxy distorted in such a way, so there must be a certain amount of mass that's causing that bending. And in that way you can calculate the amount of mass and compare that to what the luminous mass is telling you and we end up finding that these clusters have like a 200-500 times more mass than we what actually see and count up in the starlight.

Kai: Huh. How else could we tell or how else could we surmise that there is extra matter up there?

Ben: So, uh, Saul Perlmutter was involved with a collaboration which won the Nobel prize this last year and he won it for an interesting observation. We can tell how fast far off galaxies are moving away from us based on how the light that travels towards us is changes color. It turns out the faster an object moves away from us the redder the color we see gets. And if we know what color it starts at we can calculate how fast the object is moving away from us.

Kai: Sort of like tail lights on a drunk driver speeding away from a cop. It's getting redder and redder he's going so fast! That, okay, I get it.

Ben: So, we can tell that the universe is expanding because of the way far, far off galaxies moving away from us and what Perlmutter and his collaborators did was they looked at a certain type of light emitting object called the supernova type 1a. The moral of the story is that it's a really bright flash and we know what color it is. And from this, you can tell how fast these really, really distant galaxies were moving away from us. And from this he constructed a history of how our universe is expanding and it turns out that it is accelerating in its expansion. And then he used a cosmological model and Einstein's theory of general relativity to figure out how much of the different types of matter there are in the universe. And, what he came up with was astounding because, it turns out, you need to include dark matter in the model to be able to describe the evolution of the universe. So, the moral of the story is that on all of these different scales that are, you know, larger than the solar system, whether it's doing cosmological tests to see how the universe is evolving or small neighborhood tests where we look at galaxies evolving or galaxies rotating around one another, we can't describe what we're seeing without including a lot of dark matter to account for the missing gravity.

Amanda: I was going to mention that, something about just trying to simulate the universe. So, how all of the galaxies are distributed throughout the universe is dependent on what the components of the universe were after the Big Bang and then how they went to evolve and collapsed to form stars and galaxies. So, if you have any more than 25% dark matter or if you have less dark matter than 25% or depending on what that dark matter actually is, if it's normal stuff or some sort of exotic substance, that will then tell you how efficiently things can collapse and start to form galaxies or start to form stars. So, they use 25% of dark matter at a certain state, what they call cold dark matter, and based on that they can recreate, through computer simulations, what types of galaxies are around and actually, where they live and how close to each other they are. So, the overall distribution of all the large scale structure in the universe. So, that's a very good test of saying yes, there is this dark matter, it's made up of this cold stuff, and it makes up about 25% of all the stuff. So, almost all of the simulations of how we create the structure in the universe are based on this assumption. So, that's another tying observations into computer simulations for concluding that there is this much dark matter out there.

Kai: So, we've talked a lot about stuff and things, does anyone have a theories on what this stuff is, where it came from, why we can't see it, what it's going to do, why we should be terrified or not terrified depending on whether the stuff is nefarious or has evil intentions or... ?

[15:41]

Ben: That's a great question. So, there's two obvious answers to the question. The first obvious answer is it might just be stuff made out of regular material, patio chairs and whisky bottles that's just kind of clumped up and we can't see it because it's not emitting light. It's not a star. And the other theory is that maybe it's some type of particle that isn't interacting with light at all. So, these are the two theories. One of them is called the MACHO theory which stands for Massive Compact Halo Object and that's the theory that says that maybe there's just a lot of really big Jupiter sized objects, brown dwarfs, things that are not luminous. There's no nuclear fusion going on so they're not radiating light but they are floating around in the universe.

Kai: So, they're like extinguished balls of crap.

Ben: Yeah, just balls of crap floating out there. And then there's another theory that says that maybe it's just large clouds of particles that we can't touch. Little ghostly particles and that's called the Weakly Interacting Massive Particles theory, or WIMP. From basic principles, it's either stuff that we've never heard of or just balls of crap that we can't see. And so, in the Massive Compact Halo Object, the MACHO theory, they started looking out in the universe for gravitational lensing. Because, if the universe is full of these giant planets that aren't radiating light then we should see them passing between us and the stars in the background. And, occasionally, if you see one pass just between us and and one of these background objects you'll see the luminosity of the background star spike and dim. Like one of those beads of water passing between a streetlight as it rolls down a window.

Amanda: Yeah, they were just looking out from the center of our galaxy and so when you look out towards, say, Andromeda or some concentration of other stars, and you see one of these dark things passing in front then you should see some brightening of all those objects in Andromeda or say, one of the Magallenic Clouds. So, they just surveyed regions in the outskirts of our galaxy because that's we see a lot of this dark matter, a lot of these dark objects.

Ben: Yeah. So, if you watch night after night, chances are, one of these stars will have something passing between it. And the number of time you see one of these Massive Compact Halo Objects passing between us and a star should tell you about how many there are. We can do a statistical analysis and when they did that they found there was only 5% of the amount of mass required in all dark matter. In other words, they found them, they are out there floating around but there isn't nearly enough of them. You'd need 20x their number to describe the source for dark matter.

Kai: So, both theories are plausible, both added up together might account for all this undocumented, invisible stuff.

Ben: Right. So, it looks like the WIMPS won the day. Most of dark matter, by far, is composed of WIMPS.

Kai: Revenge of the Nerds.

Ben: That's right.

Kai: So, under the WIMP theory, I could totally fly a spaceship through it but under the MACHO theory I would, that would not be a good idea.

Ben: Yeah, it's like a locker room. You know, if you walk through a locker room of macho guys you're going to hit one of them whereas if it's full of wimps you can pass through and nobody will say anything.

Kai: Especially if you're dressed as an astronaut. It's much harder to get through a football team's locker room when you're in an astronaut costume. I have discovered, at any rate.

Amanda: Or as a super scientist I have to say.

Ken: But wait, in this analogy, there's a constant mass of people, so there would be like one jock and maybe like 20 wimps.

Ben: I guess one idea you could keep running through a locker room full of wimps and nothing will happen.

Ken: That's true, yeah.

Ben: Whereas if you keep running through a locker room with one macho guy eventually he'll...

Ken: He's going to punch you.

Ben: That's right.

Amanda: Right, because the WIMP is the Weakly Interacting Massive Particle so they, the WIMPS just back away, they don't ever interact with you at all.

Kai: So, how do they test the WIMP theory?

Ken: Yeah, it's more, this is in progress, how are we testing the WIMP theory because, I mean, nothing's been found yet. But, it's a really hot topic right now. There's a lot of experiments all looking for these WIMPS. So, the way that they look for it, these WIMPS are weakly interacting so, they don't interact very much but every once in a while they do and there's a lot of them going through the earth at any given time. So, if we get a detector which is sensitive enough, we can actually see these really rare interactions and we can detect them and say there it is, there's your dark matter and win the Nobel Prize.

Ben: So, when we say that it is a weakly interacting particle, it's not a vague descriptor, it's actually a very specific description. You've heard that there are four elementary forces in nature. There's gravitation, electromagnetism, so, electric charge in magnets and then there are two nuclear forces. There's the strong force which binds nucleons in the nucleus together and then there's the weak interacting force. The weak force is kind of a repulsive force inside the nucleus. Sometimes it causes radioactive decay. So, when we say that these particles are weakly interacting what we're saying specifically is that they only interact with other particles through this weak interaction. They don't have any response to electromagnetic radiation. They're neutrally charged. And that's why they don't block out the light in the galaxy, so we don't see big clouds of them the way we see clouds of hydrogen. And they don't emit light.

[21:10]

Amanda: And that's why we have such a hard time detecting it because they don't just land on our detectors like regular photons from the sun do. So we have a really hard time trying to harness them and track them and count them and try to figure out what the heck they are.

Kai: Especially cause they are going through our earth all the time.

Amanda: Yeah, hundreds of billions of these things are neutrinos from the sun are just passing through our bodies and earth all the time, without us noticing.

Ken: But let's be careful to separate neutrinos from dark matter.

Ben: Right. So, neutrinos are a type of elementary particle that gets emitted as the result of nuclear reactions. Yeah, so, the sun is emitting a ton of these and we detect them on the earth all the time. There's the SNOW laboratory in Sudbury, there's the Super Kamiokande detector in Japan. So, there are detectors that detect neutrinos a lot all of the time. Yeah, how do we know that dark matter isn't neutrinos?

Ken: There are several reasons I think. One of them as that now that we're narrowing in on what the mass of the neutrino actually is, there just aren't enough to make up the density of the dark matter that we know exists. And another one is because neutrinos are relativistic, Amanda probably has to speak to this, but if I understand, if all the dark matter was relativistic it would have washed out structure formation. We would never actually get anything forming.

Amanda: Exactly. Exactly. It would be too hot. You wouldn't be able have particles get cool enough so that they could actually start to condense and form stars.

Ben: So, in the WIMP theory the idea is that there is some unknown elementary nuclear particle that was present in the early universe when everything was really, really hot before nuclei started forming. These elementary particles, so they stopped interacting with atoms as the atoms started forming and as the rest of the universe cooled the universe just ended up full of this dark matter detritus. If you give dark matter too much kinetic energy it keeps the universe from evolving the way we model it evolving.

Amanda: Yeah. It can't cool enough to form any of the structure so we'd never get a galaxy.

Ken: Yeah, we wouldn't be here. That's the question.

Kai: Well, I'm curious where this goes. I'm wondering what the next steps are. I guess if we're in the middle of testing the WIMP theory what are some of the new ideas that people are kicking around for trying to finally figure out a way to measure this stuff?

Ken: Oh, there are tons of new ideas to try and figure out how to measure this stuff. So, the problem is, like we touched on, these things only interact very rarely in your detector. Most estimates put it like less than one interaction per hundred kilograms of mass per day. So, you need a lot of, you know, mass and stuff to actually detect these things. You need to let it run for a long time. But the way you detect them is the WIMP comes in, essentially and just, in the brute force way, hits your nucleus of the atom that you're trying to use to test it and that nucleus recoils and as it recoils it deposits energy along the path of its recoil. And then there is a whole bunch of different ways, essentially, to take that really small energy deposit, which is like 10 keV, which is a very small energy deposit, essentially. And magnify it and make it something you can actually see and then make it something we can distinguish from background. Like I said, there's lots of experiments right now trying to do this very thing in very different ways.

Ben: Yeah, tell us about noble element detectors Ken because that is awesome.

Ken: Yes. Yeah, so that's kind of like a hot new thing right now is these noble element detectors. So, you take a big detector and you fill it with xenon or you fill it with argon or some are wanting to fill it with neon, and essentially, like I said, the particle comes in, it hits the nucleus, it bounces off of it, the nucleus skids along and as it skids along the atoms along its track get excited a little bit, and then as they relax they give off a flash of light. So, you get this burst of light in your detector but then, at the same time, this skidding nucleus frees electrons, and you use an electric field to drift these electrons through your detector and then you accelerate them again in a different phase and you get a second flash of light and you're able to use these two flashes of light to actually see what happened inside your detector. And if you could see the hand motion I was making right now it would all be much clearer I'm sure.

Kai: Yeah. I guess I can't really picture any of the things that you're talking about so I don't know what the instruments would look like or the read outs or the formulas involved so it becomes a little hard to follow when we're talking about a bunch of different instrumentation. That's my only issue.

Ben: Okay. I've got a sweet analogy that gives you an intuitive picture of what's going on. And then I'll make Ken re-explain it to you.

Amanda: Does it involve bees?

[25:46]

Ben: No, it involves mice. So, when I lived in Kingston I had a mouse problem in my house. And the thing about mice is that you're never sure that you have them. You wake up in the morning and you have mouse poop everywhere but you never see the mice and you never hear the mice. And so what I did was I put out mousetraps and they wouldn't trap the mice but the mice would wander past them and it would disturb the system enough that the mouse trap would snap and make a big sound and flip out. And so from the mouse trap flipping when it did I could tell that I actually had mice something moving through, setting these clappers off. So, the principle in this is the same, you set up a system and then if a WIMP is aimed just right at a nucleus it won't just pass by it, it will kick it as it's passing. And so you set up these systems and they are very sensitive to changes so that when a WIMP comes through and it kicks one of these atoms out of the way you see it, it causes a flash of light.

Kai: And one day you come back and there's just a tiny paw and a little trail of blood and you feel like a bad, bad person.

Ben: Yeah.

Kai: Maybe Ken could explain how that analogy works in the hunt for dark matter.

Ken: So, that's an interesting analogy. But the real problem is, god, how do I extend your analogy? In the middle of the night there are a lot of cats that come by and set off your traps and it's really tough to tell when a trap has been set off by a cat or when it's been set off by the mouse. And there are way more cats than there are mice. So, the real problem, the real problem that everybody has in the dark matter game, is trying to separate the cats from the mice. And what that translates to in the real world, if we can please stop dealing with this analogy is, there's a lot of background. So, in these detectors, I mean, they're built out of material, right? Most of them are just big tanks of material, for example, a big tank of Xeon. And all the tank, everything the tank is built out of, and the Xeon itself, has radioactive particles in it that can mimic your signal. So, the real game is not making a detector that can detect things, we're pretty sure we can do that. But the real game is trying to tell what was caused by a WIMP from what was caused by a background event and that is the, that is the really hard part. And that is what everybody is spending all their time and energy on.

Kai: The false alarms.

Ken: Exactly. And the false alarms are orders of magnitude more prevalent than the actual signal. Mostly because we've seen a lot of alarms and we haven't really seen a signal yet, for the most part.

Kai: My brow is furrowed.

Ben: Okay, what's up.

Laughter.

Kai: Well, I guess I'm trying to figure out, we're in the middle of this, we're in the middle of testing the WIMP theory, and we're pretty sure there's both, brown dwarfs kicking around that account for maybe 5% of this extra matter. And then there's still a huge amount of stuff that we still haven't really been able to capture or identify or get a real reading on or measurement of. I'm wondering, is it kind of like the tree falling in the forest when no one's around. Like, this stuff has presumably been around since the early days of the universe right? So, discovering it, I guess I'm trying to figure out what the practical applications of this emerging knowledge. Why does it matter that we're surrounded - that wasn't a pun. Why is it significant that we're surrounded by all this stuff if it doesn't interact, with, even, itself very much, let alone us. Does it change how we model the future of the universe, does it change how we understand the solar system in which we live?

Ken: That's a great, I mean, the practical application question is the greatest question and the toughest one to answer. I would say that a lot of dark matter, at least from my point of view as an experimentalist, a lot of dark matter is really science for knowledge's sake. You're right, I mean this stuff has been around for as long as the universe has been around and it's going through us all the time and it really doesn't have an affect on us. But we really want to know, we want to be able to characterize everything and understand the universe. To my mind, it's really hard to predict what comes from any of this. The more that we know the better we can predict things for the future.

Kai: Right.

Amanda: And also, in terms of simulating what the universe is, on a large scale, just understanding the distribution of where galaxies are, we do a pretty good job. But, there's still things, like from the Southern Hemisphere you can look up and see the large and small Magallenic clouds, these two little dwarf galaxies that are gravitationally bound to our Milky Way galaxy. But, inside of our models, we have a really hard time being able to predict the existence of these things. So, in a typical model, we actually predict too many so, ah, we have a hard time predicting exactly the large and small Magallenic clouds. But overall the Milky Way system should have something like sixty of these small little things but we just don't see them when we go out there. So, these tiny little dwarf galaxies are completely dominated by dark matter. And since we can't really observe it and we can't figure out any way to understand what it is, we have a hard time incorporating that into our models. So, the big question of how we got here, how the Milky Way is here, there are a lot of details that we don't understand and a lot of it comes from how dark matter actually interacts.

[31:06]

Ben: Yeah. So, that about settles it up. So, thank you Ken, thank you Amanda. You've done very well, you've pleased me. Your efforts have born fruit and that fruit is sweet. Amanda, you get a coconut.

Amanda: Oohhhhhh. If only I could get into it.

Ben: And Ken, you get a little baby mouse paw to eat.

Ken: Awwww. Delicious.

Ben: Ahh, so, I'd like to thank my guest, Kai Nagata. Thank you for very much for coming on.

Kai: Hey, thank you for um, you know, forcing me out of my comfort zone and bringing me on the show.

Ben: I think you did a wonderful job asking questions and I wish you all the luck in the future.

Ben: So, listeners, you can email us, if you'd like to contact us, at barn@titaniumphysics.com or you can follow us on Twitter at @titaniumphysics. You can visit our website at www.titaniumphysics.com or you can look for us on Facebook. If you have a question you would like my Titanium Physicists to address email your questions to tiphyter@titatiumphysics.com and if you are a physicist and would like to become one of my Titanium Physicists email physics@titaniumphysics.com we're always recruiting. Feel free to leave a review on iTunes reviews as well, it helps people find the show. So, the Titanium Physicist podcast is a member of the BrachioMedia. If you've enjoyed our show you might also enjoy Science Sort Of or the Weekly Weinersmith, please check them out! The intro music is by Ted Leo and the Pharmacists and the end music is by John Vanderslice. Good day my friends and remember to keep science in your hearts.

[33:37]

Kai: Didn't Yoda already figure this out on Degaba like 800 million years ago?

Ken: But the citation was lost.

Laughter.

Ken: It doesn't count anymore.

Kai: But is this what, is this what Yoda was talking about? Is this the "Force"?

Ben: No. It's weak. The force is strong. At least in Luke Skywalker.

Kai: And his sister.

Ben: Right.

Kai: Can I ask a journalistic question Ken?

Ken: Yeah, absolutely.

Kai: I'm just curious who's funding all this research.

Ken: There are lots of people funding this research. In the U.S. the, both the NSF and the DOE are funding the research. In Canada, NSERC is funding several different ones. There's

Kai: Is the DOE the Department of Energy?

Ken: Yes. Yeah.

Kai: Okay.

Ken: If we're in Canada...

Kai: So, basically...

Ken: ...there's a number of different experiments. Yeah, the government. The government funds this stuff. There's no private funding for the most part.

Kai: And... Are... Is the involvement of the Department of Energy any indication that they expect some kind of return on the research in terms of solving America's energy crisis or is this just the most convenient administrative organ to disperse the funds for knowledge's sake?

Ken: That, that is a great question. Essentially it's just a way to disperse the funds, more or less. The Department of Energy gets involved in some pure research areas and this happens to be one in which they have gotten involved.

Kai: So, we're not seeing any interest from the private sector, you said we're not seeing any interest from the Pentagon, we're not seeing any interest, so far, from NASA. It's coming from the DOE.

Ken: Yeah, I mean, it would be tough to, I mean some of these things would be great, right. If you could figure out how to make an engine that runs with, that is powered by dark matter, I guess you could probably get private interest. I suppose the Pentagon would be interested if you could weaponize it somehow. But I think that's probably and hopefully impossible. But for the most part, yeah, it's government research funding that's actually going into this stuff.

Kai: And is that funding stable or is that, or are you having a harder and harder time... Amanda you were talking about justifying your research when you're applying for grants. I'm curious, whether in Canada, Australia or the States right now, it's a bright future for pure science research or whether people are worried about loosing their funding.

Ken: People are most certainly worried about loosing their funding, absolutely. And it's gotten to the case now where essentially there are many ways to do the same thing. For example, with the Xenon detectors, there are several different Xenon projects, but governments now are kind of saying we're only going to fund one. We're going to fund the one that looks the best and everyone else is out of money. It is tight right now, I mean, money is obviously scarce.

Amanda: Yeah, that's absolutely an issue and for the particle physics experiments they are really expensive so there's not a whole lot of private funding that can really occur to fund those things. I know the LHC in Europe, I mean, there are lots and lots of different countries on a national level that are contributing to that but if that's all of your research science budget maybe it comes away from something else like from some astronomy telescope or something in order to keep up your end of what you've agreed to contribute to, to this big experiment.

Kai: Hmmm. Yeah, I was just curious. Thanks for giving me the picture on the research scene because I happen to know some researchers in math and physics and they've found that there's been a politicization, basically, of how the money goes out depending on what you're working on, so... I was curious.

Ken: I mean, I think...

Amanda: That's true, you always want something to put in those, those exciting buzzwords in order to get, to get people excited about it regardless of what the details are that you do. That's just kind of the game that you have to play I think.

[37:36]

Ken: And I think, particularly in the dark matter field, I mean, it has a couple advantages, it's a pretty sexy field right now, there's a lot of interest. But also there's competition with other countries, other countries also have dark matter experiments so you don't want to let the other countries get ahead, essentially. So you're able to play that sort of thing to get more funding. But, it's still, Amanda's right, this is expensive physics that we're talking about here so it's, the money is not easy to come by.

Kai: Wow, let's hope the Russians don't launch a dark matter Sputnik. We're all going to feel really, really ashamed.

Kai: Cool, um, sorry, back to you Ben.

Ben: I thought that discussion was fantastic and I might leave it in here. Frankly because I don't think you should be able to separate politics from basic research especially if basic research drives so much of its impetus from public funding and ah...

Kai: Yeah.

Ben: They have politicized it. So, I might leave the discussion in just because it's, man that's a message I want to get out there.

Kai: I'm also a member of the paying public and I actually, the same way I think that opera is awesome, I like pure physics research. And it actually doesn't bother me along with like, potholes and hockey arenas, to fund scientific research. I think that's a really cool use of tax dollars. But, I also like having it explained one on one by some of the leading minds of the field so that I sort of get a sense of why people are excited about it. And, knowing the funding picture is actually, I think, pretty interesting as a citizen, as one who is actually paying into the government funding bodies that in turn pay for the research.

Ken: The one thing I would add Ben, not to continue this too much longer but, Canada is in a great position because they have the SNOW lab facility. There's a number of dark matter experiments that are going on in there right now. And it is, effectively, the best facility in the world and it's been entirely funded by several different branches of government. But, you know, NSERC and FedNor and a number of other branches have come together to make this really the best place to do underground physics in the world. So that's just my plug for SNOW lab in general.

Ben: Sweet. Alright.